

DIAMOND NANOPARTICLES AS A SUPPORT MATERIAL FOR FUEL CELL ELECTROCATALYSTS

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Abstract

The conventional support material for fuel cell electrocatalysts is high area carbon black. This material can undergo slow oxidation at the potentials existing at a fuel cell oxygen cathode [0.7–0.9 V vs. reversible hydrogen electrode (RHE)]. Conductive diamond in a high area form might be an attractive substitute for carbon black. Preliminary characterization and electrochemical results will be presented.

INTRODUCTION

As fuel cell technology matures and approaches the point at which it will see widespread implementation, there is a continuing need to make improvements in the characteristics of the electrodes, particularly, the electrocatalytic activity and lifetime. One of the major problems with the fuel cell oxygen cathode is that the conventional electrocatalyst support material is carbon black, which can undergo slow oxidation at the potentials that typically exist at this electrode (0.7–0.9 V vs. RHE). At the fuel cell anode, whether hydrogen or methanol, the potentials are much lower, and there is significantly less oxidation of the support, but even in this case, the potential under heavy load or short circuit conditions could accelerate the oxidation process. In addition, there is the possibility that the catalyst nanoparticles could have mobility on the carbon surface and slowly agglomerate, particularly at elevated temperatures.

Conductive diamond, typically boron-doped, has been used recently extensively for electrochemical measurements due to its wide potential operating range. It is intriguing to consider diamond as a replacement for carbon black in the fuel cell. Diamond is usually considered to be prohibitively expensive, but detonation diamond nanoparticles are relatively low in cost. These nanoparticles have been shown theoretically to have a preferred size range of 2–5 nm due to the special stability of the bare (non-hydrogenated) surface in this size range (1).

We are in the process of characterizing a series of diamond powders, including several detonation samples, from various sources. The techniques being used include x-ray diffraction, x-ray photoelectron spectroscopy, Raman, Fourier transform infrared spectroscopy, transmission electron microscopy and electron energy loss spectroscopy. We are also studying methods for introducing dopants into these particles, as well as methods for modifying their surface chemistry as a means of attaching metallic nanoparticles more firmly, so that they will not tend to agglomerate. The diamond surface, particularly for the nanodiamond particles, is eminently suited for surface modification, because the surfaces appear to be extremely well-defined.

RESULTS AND DISCUSSION

We have examined thus far a total of four diamond powders, two of which are detonation samples, one from Russia and the other from the Ukraine (Alit). The others, from Alfa-Aesar and from China, consist of larger particles, on the order of hundreds of nanometers and micrometers, respectively. The problems we are addressing include how to purify the nanodiamonds and how to prevent their agglomeration. The purified sample received from Alit is relatively pure, according to the measurements we have carried out, including TEM (Fig. 1). This shows that the particles have predominantly the shape predicted theoretically, i.e., a truncated triangular (nearly hexagonal) shape in a two-dimensional projection, which would be expected if the view were from a vector perpendicular to the (111) plane. There are also some cubic particles, which would be expected if (100) planes were exposed only. Now that we are confident that the nanoparticles appear to be rather perfect single crystals, we can proceed to employ the techniques that have been developed in previous work at the University of Tokyo (2), as well as techniques that have been developed by a number of other groups to functionalize diamond surfaces.

